EMERGENCY CRICOTHYROIDOTOMY IN TACTICAL COMBAT CASUALTY CARE

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3 June 2015

Keywords: Surgical cricothyroidotomy, airway, tactical combat casualty care,

Proximate Cause for this Proposed Change

The performance of a surgical airway is an infrequently performed but occasionally lifesaving procedure on the battlefield. Since a combatant who sustains a wound that damages the upper airway structures is often in extremis shortly after the wound is sustained, this is a procedure that must be performed by the individual who is caring for the casualty at the point of injury – the combat medic. There are a variety of techniques and equipment available to perform this technique. In the past, Tactical Combat Casualty Care has not recommended a specific equipment item for the performance of surgical airway. A recent study done using Army 68-Whiskey medics trained to the Emergency Medical Technician – Basic (EMT-B) level found that the use of a new equipment item – the CricKey – resulted in surgical airways being performed on fresh human cadavers by medics faster than with the standard open surgical technique and with a 100% first pass success rate compared to a 70% first pass success rate using the standard technique. At this time, the CricKey has the best supporting evidence for enabling successful performance of surgical airways by combat medical personnel and is recommended as the device of choice for TCCC.

Background

Surgical cricothyroidotomy (SC) is a critical emergency airway management technique. This potentially life-saving procedure is rarely required and rarely performed. (1-5) While SC rates are nearly double in the military setting compared to the civilian setting, they still occur in less than 1% of all trauma admissions. (6)

SC is the final pathway in the "can't intubate, can't ventilate" situation in all difficult airway algorithms. It is usually deferred until all other options for airway management have failed. In many instances the patient is critically ill and in extremis (2-4). A high complication rate, especially in the prehospital setting, is also associated with SC. (1, 6-7) Overall survival rates for those who undergo SC are low and likely reflect the fact 30 to 80% are in cardiac arrest prior to the procedure.(7) Few of these patients survive with a good neurological outcome.(1, 4, 6)

Complications are frequent and include: failed attempts, bleeding, injury to thyroid vessels, incorrect anatomic placement, main-stem bronchial intubation, misplacement into subcutaneous tissues, esophageal injury or intubation, and damage to associated airway structures. (3, 6-11)

The infrequency with which SC is performed, the critical nature of the patients who require SC and the risk of significant complications combine to make SC a high risk, anxiety provoking, and often difficult to perform procedure. Success rates are variable among providers ranging from 62-100%. (7)

Performing SC is even more difficult in the tactical setting where there are often few medical providers, multiple casualties, ongoing combat nearby, and poor lighting. The military tactical environment is further defined in Box 1. Combat medics performing SC in Iraq and Afghanistan failed to cannulate the airway in 33% of SC attempts. (6) Historically 1-2% of battlefield deaths and 8-15% of potentially preventable deaths are caused by traumatic obstruction of the airway, usually from penetrating maxillofacial or neck trauma. (12,13).

Although numerous SC techniques have been described, there is no consensus in the literature as to which technique or device is superior or preferred. (5) Most studies of SC techniques are performed with physicians already familiar with the anatomy of the airway and a variety of airway management techniques. Yet in the military prehospital setting, the operator most likely to perform SC in a timely and lifesaving manner will be a combat medic, corpsman, or pararescueman (PJ). These providers will have little airway management experience outside the training lab. Few if any will have managed an airway of a live patient before having to perform a SC on a fellow unit member who is likely a personal acquaintance.

Surgical cricothyroidotomy techniques for the tactical environment must take into account the injury patterns encountered, the level of training and capability of the medics, equipment availability and the tactical environment. The optimal technique should minimize the chance of error and failure. It should be fast, simple, involve few steps or pieces of equipment, and be easy to train and sustain for a large number of combat medics who do not have ongoing exposure to trauma patients in peacetime.

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Box 1

- Pre-hospital providers (medics) likely not experienced with orotracheal intubation (OTI)
- Often a single provider has responsibility for multiple casualties
- Limited equipment
- Supraglottic airways (SGA) (King, ETC, LMA) of questionable utility in semiconscious trauma patients or those with facial trauma
- Suction not available or of poor quality
- O_2 not available
- Paralysis (neuromuscular blockade) not possible or impractical
- High incidence of face and neck trauma (bleeding, disrupted anatomy, aspiration of blood)
- High incidence of traumatic brain injury (TBI) and secondary brain injury from hypoxia
- Noisy, dark, extremes of temperature, vibration

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Discussion

Techniques;

The medical literature describes many different SC techniques. Several studies have been done that offer a comparison of one technique over another. This literature is often difficult to interpret because studies compare different types of providers and different types of models. Studies have been done using anesthesia providers (5, 14-15), critical care physicians (16), emergency physicians (10,17-18) and prehospital providers. (19) Some compare results of only a few experienced providers performing multiple repetitions of the same procedure (20-21) while others include medical students and residents along with experienced physicians.

Many different techniques and variations of surgical cricothyroidotomy have been described. Below we discuss several of these and attempt to identify potential sources of procedural difficulty, error and complications.

OPEN TECHNIQUES

OPEN SURGICAL TECHNIQUE

The “standard” open SC technique and its variations typically involve a horizontal or vertical incision through the skin, a horizontal incision through the cricothyroid membrane (CTM), a dilator or tool to enlarge or maintain the opening through the CTM, commonly a finger, tracheal hook, curved forceps, or scalpel handle, followed by insertion of an endotracheal or tracheostomy tube. (1, 22-27)

There are several difficulties inherent to the standard open SC technique. First, surgeons are much more familiar with surgical anatomy of the neck and often prefer a horizontal to a vertical skin incision. This is similar to the familiar tracheostomy incision with which most surgeons are very comfortable. (11) The horizontal skin incision is the technique taught by the American College of Surgeons’ Advanced Trauma Life Support Course (25) and is thus the technique often preferred and subsequently taught by surgeons to other providers attending ATLS classes. Non-surgeons, such as emergency physicians, anesthesia providers, critical care physicians, and prehospital providers, who may be required to perform SC will not have performed dozens or even hundreds of tracheotomies as a regular part of their training and practice, and therefore will not be as familiar with the anatomy of the neck as a surgeon.

For the non-surgeon and less experienced operators such as prehospital providers, we advocate a vertical skin incision. A vertical incision maximizes exposure of the appropriate anatomy for providers not as familiar with the surgical anatomy of the neck. This incision can then be extended at either end if further exposure is needed. Our previous autopsy study showed that four out of five failed SC cases had horizontal incisions, in some cases, multiple horizontal incisions, yet the airway was not successfully cannulated. (28)

A vertical midline incision also potentially minimizes bleeding. Goumous studied 107 autopsy specimens specifically examining the vascular structures (arteries and veins) located in the cricothyroid space that lie within one centimeter of the midline. Veins with a diameter of greater than two millimeters were considered a significant source of bleeding during the performance of a SC. Goumous and his colleagues found that 10.2% of 107 cadavers had veins greater than 2 mm in diameter located in the midline whereas 30.8% of specimens had these vascular structures within 1 cm from the midline. (29)

The “rapid four-step technique” (RFST) is a simplified version of the open surgical technique designed to increase speed by using a single horizontal puncture that simultaneously extends through the skin and CTM followed by insertion of a tracheostomy tube through the opening. By combining the incisions into one single incision and by not using a dilator, this technique was shown to be faster than the standard technique in a cadaver model. Complications with the RFST have been higher in some studies compared to the standard SC.(8, 9) Bleeding risk is potentially increased by using a single large, relatively deep, transverse incision.

Bougie Aided

Another modification of the open surgical technique is the bougie-aided cricothyroidotomy (BAC). This technique involves insertion of a gum elastic bougie into the CTM after incision. This may eliminate the need for forceps or a tracheal hook, permits the operator to have both hands free once the bougie is inserted into the trachea and allows for easier insertion of the an endotracheal tube. (30, 31) The BAC also provides the operator tactile feedback if the bougie is in the trachea by vibrations produced as the coudé tip passes over the cartilaginous rings of the trachea, as well as potential “hold-up” of the bougie as it reaches the level of the carina. (32) The BAC can thus give confirmation of correct placement into the trachea. The BAC has been shown to be faster than the standard technique in an animal model. (32)

Percutaneous Techniques

Other SC techniques include percutaneous placement of both cuffed and un-cuffed airway cannulas using either a trochar or a wire-guided Seldinger technique. Percutaneous techniques do not require an incision or exposure and direct visualization of the CTM.

Tube over a needle

While percutaneous devices may appear simple to use and one may think they minimize bleeding by eliminating the need for an incision, tube over the needle techniques have several potential complications. Benkhadra compared one such device, the Portex Cricothyroidotomy Kit (PCK) (Smiths Medical, St. Paul, MN), to a common wire guided kit and documented more failures (20% vs 5%) with the PCK. The PCK also caused 8 major complications including 4 perforations of the trachea out of 20 placements. (20) Confirming proper placement of these devices following insertion is problematic. There has been at least one recorded case of an airway device placed in the pre-tracheal subcutaneous tissue in a US casualty in Afghanistan using a tube over needle airway that went unappreciated at the time.

(Office of the Armed Forces Medical Examiner-Feedback to the Field Case # 22042011) Inserting a large trochar through the skin risks injury to the posterior tracheal wall (5,14,20) and subsequent insertion into the esophagus as a greater degree of force is required to puncture through the skin and CTM simultaneously. Abbrecht showed the risk of injury to the membranous trachea and esophagus is directly related to the size of the trochar and force required to insert it. (33) Also, some of the trochar devices are un-cuffed which will not protect from aspiration of vomitus or blood, and are liable to inadequately ventilate the patient due to gas leakage through the upper airway. (7) Johnson, in a study of paramedic students, found the open surgical technique faster than a percutaneous device with equivalent accuracy. (19)

WIRE GUIDED:

Wire guided techniques such as the Cook Melker are described predominantly in the anesthesia literature. This technique is more intuitive for anesthesia providers facile with wire guided vascular access as opposed to an open surgical technique. Studies comparing wire guided techniques to open SC's show mixed results. (5,10,15,16,19,24) Prehospital providers will not typically have experience with wire guided vascular access compared to surgeons, anesthesiologist, critical care and emergency physicians. Without extensive experience using wire guided vascular access, performing an emergency cricothyroidotomy using a Seldinger technique on a critically ill patient with a small wire and multiple steps will likely be very difficult given the degradation of fine motor skills common in high stress situations. (7) Kinking of the wire and failure to feed the wire account for failures in 3-25% of instances when using this technique. (5,10,16) A wire guided technique will be even more difficult in the prehospital setting where lighting, patient exposure and other environmental conditions will be less than optimal.

CANNULAS

TRACHEOSTOMY TUBES

Many surgeons prefer a tracheostomy tube as their airway device of choice over an endotracheal tube. Again, this is related to their comfort level with the familiar tracheostomy. However, tracheostomy tubes are not made nor shaped for SC. Most tracheostomy tubes are rigid and do not lend themselves to conforming to the anatomy of the CTM. In the hospital setting, the size and design of the tracheostomy tube chosen depends upon the body habitus, anterior neck anatomy and pathology of the patient. Multiple sizes and designs are usually readily available in the hospital setting. In the prehospital setting, the variety of airway types and sizes will be limited.

When choosing an airway cannula for SC one must also take into account the anatomic dimensions of the cricothyroid space. Given that the vertical CTM dimension in the average male is 10 mm, any airway cannula with an outer diameter larger than 10 mm will difficult to insert. A 4.0 Shiley, (Shiley™ Tracheostomy Tube Cuffed with Disposable Inner Cannula, Covidien, Mansfield, MA) a relatively small tube with an ID of 5 mm, has an outer diameter of 9.4 mm. Non-surgeons may have a difficult time inserting a tracheostomy tube into the CTM as this may require significant force. (32)

ENDOTRACHEAL TUBES

When used for SC, the ETT is being used in an improvised fashion. The distance from the CTM to the carina is approximately 10-12 cm in the adult. Using an endotracheal tube also has some inherent potential drawbacks. A cuffed 6.0 ETT (endotracheal tube) is commonly recommended for SC. The outer diameter of a Mallinckrodt 6.0 cuffed ETT is 8.2 mm. The pilot balloon inserts onto the ETT at the 16 cm mark. After inserting the ETT through the CTM, particular attention should be given to avoiding advancing the ETT too far into the trachea, which could result in a main stem bronchial intubation. Conversely, an adequate length of the airway cannula should be advanced into the trachea to prevent accidental extubation. The overall length of the Mallinckrodt 6.0 ETT is 26 cm to the 15 mm adapter. Because of its excess length, compared to the distance from the CTM to the carina, main stem intubation rates of up to 15% have been documented in the prehospital setting. (3,6)

The 6.0 ETT, even when "cut down" to the pilot balloon tubing insertion at the 15 cm mark leaves approximately 10-12 cm of excess ETT length that extends outside of the incision. While this excessive length has little effect on manual ventilation of the casualty, this long section of tubing is difficult to secure to the patient's neck and is prone to either dislodgement, tube kinking, or migration into the main stem bronchus, especially during patient movement and transport when loss of the airway may not be readily apparent.

MELKER AIRWAY

We recommend a cuffed Melker or similar airway (Cook Critical Care, Bloomington, IN) designed for insertion into the CTM. When tracheotomy or endotracheal tubes are used for SC, they are being used in an improvised fashion. Unlike a conventional ETT, which has a beveled tip but blunt edges at the lumen, the Melker has a circumferentially tapered end that when combined with the dilator inserts much more smoothly than an ETT or a tracheostomy tube. The Melker 5.0 tube has an OD of 7.4 mm and is therefore more easily placed thought the CTM, compared to the 8.2 mm OD for a 6.0 ETT or 9.4 mm OD for a 4.0 Shiley. The Melker's total length is 9 cm so main stem intubation is not likely.

A cuffed tube reduces the potential for aspiration of blood, secretions, or vomitus. The average diameter of the adult male trachea is 25 mm. Using an airway with a cuff that is less than the tracheal diameter when inflated places an already potentially seriously ill patient at risk for aspiration The Melker cuff diameter when inflated with 10 cc of air is up to 29 mm in diameter compared to the 23 mm diameter for a typical 6.0 ETT.

The Melker tube has flexible arms that extend laterally (see Fig 1) along the patient's neck. These have loops used to secure the airway in place with a cloth ribbon or tape. Thus the Melker is much easier to rapidly secure compared to an ETT, which decreases the risk of dislodgement or migration into the main stem bronchus during patient transport or movement.

Training Models

There is no accepted standard for patient models. Several different patient models have been described. These include human cadavers (10, 19, 20), animal models (32) plastic manikins (5, 17), lung models (30) and preserved pig larynxes. (14, 35) Comparisons of SC speed and success rates will likely vary across different training models. A plastic manikin will not likely perform the same as an animal model or cadaver. Likewise, a caprine (goat) animal model will present training variables different than an ovine (sheep) model or a porcine (pig) model. Each model has different airway anatomy, skin thickness and the like. Cadaver models will likewise have some differences. The tissue elasticity of fresh cadavers has a different feel than embalmed or preserved cadavers. Animal models and infused cadavers can bleed during the procedure while manikins and non-infused cadavers do not. Cadaver models are also most often elderly patients who may have little subcutaneous tissue and easily discernable anatomy while a pig model will have a thick neck and challenging anatomy. (18)

CRICKEY TECHNIQUE

The CricKey (CK) is a curvilinear round introducer with an overall length of 19 centimeters (cm), an upturned distal tip, and a diameter of approximately 5 millimeters (mm). It was designed to fit into a 5.0 mm ID cuffed Melker cricothyroidotomy airway cannula. The CK combines the functions of a tracheal hook, stylet, dilator, and bougie when incorporated with the Melker airway (Figure 1). The CK design is based on the shape and curvature of Levitan's scope used in a previous study of fiber optic guided SC in a sheep model. (37)

If the CK is correctly inserted into the trachea, the operator may appreciate the vibrations of the anterior tracheal cartilaginous rings as the distal tip of the CK passes over them. If the CK is inserted into the subcutaneous tissue and not in the trachea, the operator can see the distal tip tent the skin of the neck. If the device is correctly inserted into the trachea, no skin tenting is visualized.

The CK technique eliminates several potential complications, errors and sources of procedural difficulty. We recommend a vertical midline skin incision followed by direct visualization of the CTM. This allows maximal exposure of the anatomy and extension of the incision if further exposure is needed while decreasing the risk of bleeding. While the potential for complications remain with an open technique, complications associated with wire-guided and percutaneous techniques are avoided. Visualizing the CTM reduces the likelihood of subcutaneous or esophageal placement. We believe adequate exposure, visualization, and direct palpation of the CTM is critical for providers who do not have extensive experience with surgical airways. We incise the CTM and insert the tip of the device into the trachea. The tip of the device secures the opening into the trachea and gives the operator the ability to lift and manipulate the trachea. The device has a blunt tip that is curved upward thus minimizing the risk of injury to the membranous trachea or esophagus. Since the CK combines the functions of both the bougie and a dilator and incorporates them within the airway cannula as a single unit, the result is a much more compact/efficient device that is easier to handle, requires fewer steps or additional equipment such as forceps, tracheal hooks or dilators.

Like the BAC, the CK technique also provides tactile feedback if the device is placed correctly in the airway as the tip passes over the tracheal rings. The coudé tip of the CK is always oriented anteriorly allowing it to consistently make contact with the tracheal rings as it is advanced caudad. This is not always the case when utilizing the BAC. Although the BAC is initially inserted through the CTM with the coudé tip oriented anteriorly, inadvertent rotation of the bougie 180 degrees aligns the coudé tip with the smooth posterior wall of the trachea where no vibrations could be felt. The CK also provides visual feedback if the device is placed incorrectly into the subcutaneous tissue by tenting the skin. No skin tenting is present if the device is in the trachea. Having both tactile and visual confirmation of proper placement is critical in the noisy, low-light prehospital setting. A conventional gum elastic bougie is approximately 70 cm in length and is designed for oral insertion, making it somewhat ungainly for use in SC due to its excessive length, whereas the total length of the CK is less than 20 cm.

In a recent crossover study of 15 US Army 68 Whiskey medics, the CK technique took less time to perform and had no first attempt failures when compared to a standard open surgical technique with this group of relatively inexperienced medics performing the procedure on fresh human cadavers. (38)

One hundred percent of the CK insertions (15/15) were successful on the first attempt whereas 66% (10/15) in the standard cricothyroidotomy group were successful on the first attempt (p =0.042). Two participants required multiple attempts to place the airway in the standard group, one required 2 and another 3 attempts, but were ultimately successful. Three participants in the standard group three failed to cannulate the airway. One participant placed the airway into the esophagus. Two others placed it into the soft tissue of the neck.

Procedure time for the CK was faster with a median time of 35 seconds [95% confidence interval (CI) = 33 seconds to 37 seconds] compared to 72 seconds using the standard technique [95% CI = 52 seconds to 92 seconds] (p = 0.001).

Based largely on the findings of this study, combat units have begun to field this device for their combat medics. Initial feedback has been positive: "I received a quick class from LTC Mabry on the device, then taught a new medic how to use the device……The medic had a cric in place in under 25 seconds and secured in less than a minute….. this device will be the standard of equipment used by all Ranger Medics for surgical cricothyroidotomy. (Personal communication, MSG Curt Conklin, 75th Ranger Regiment, 26 Feb 2015)

Note that the study demonstrating success with the CricKey entailed 5 repetitions of both the study CK procedure and the standard surgical airway control procedure. Five is the minimum number of procedures recommended in a recent review of surgical airway training methodology to achieve proficiency in the technique. (39) Since incorrect location of the incision is a demonstrated cause of failure in the performance of surgical airways, training in this procedure should include anatomically precise airway manikins as well as the use a skin marker to demonstrate knowledge of the correct position of the incision on the neck of a fellow student in the training class. (39)

Conclusions:
Of the techniques and cannula types reviewed in this paper, we recommend an open technique via a vertical, midline incision. This approach will maximize anatomic exposure, minimize bleeding, and allow for extension of the incision at either end if the initial incision is not optimally placed.

Once the incision through the skin and CTM is accomplished, the most effective airway instrument type, in our review, is the CK, which eliminates multiple sources of difficulty. In contrast, the techniques below pose additional risks for procedural difficulty and potential failure to cannulate the airway.

- The standard surgical approach (horizontal skin incision) is challenging for non-surgeons who are less familiar with external landmarks and anatomy.

- The rapid 4-step technique poses an additional bleeding risk and opportunity for misplacement as well as the potential for injury to the airway and adjacent structures.

- The wire-guided approach has too many steps, requires very fine motor control, and is predisposed to wire kinking

- The tube over needle approach can lead to perforation of the posterior tracheal wall and subsequent cannulation of the esophagus and increased risk of aspiration.

The preferred airway cannula-type, based on our review, is the Melker or similar airway cannula which has an appropriate external diameter to internal diameter ratio and has external wings allowing the airway to be secured without compressing the patient's neck. Dire circumstances may require innovative use of existing supplies, but improvised use of other airway cannulas in the setting of an acutely injured and compromised airway can lead to additional complications. Traditional tracheostomy tubes are too rigid and do not mold well to the patient's anatomy, while the excess length of endotracheal tubes, even when "cut to size," can lead to main-stem bronchial intubation and external entanglement, especially in tactical settings.

At this point in time, the CricKey has the best supporting evidence for enabling successful performance of surgical airways by combat medical personnel and is recommended as the device of choice for TCCC.

Whatever surgical airway procedure is used, training for this procedure should include a minimum of 5 repetitions of the procedure and the student should demonstrate his or her mastery of the precise location for the skin incision by marking the proposed incision site on a fellow TCCC student as part of the training evolution.

Current Wording in the TCCC Guidelines:

Care Under Fire:

N/A

Tactical Field Care

2. Airway Management
   - a. Unconscious casualty without airway obstruction:
     - - Chin lift or jaw thrust maneuver
     - - Nasopharyngeal airway
     - - Place casualty in the recovery position
   - b. Casualty with airway obstruction or impending airway obstruction:
     - - Chin lift or jaw thrust maneuver
     - - Nasopharyngeal airway
     - - Allow casualty to assume any position that best protects the airway, to include sitting up.
     - - Place unconscious casualty in the recovery position.
     - - If previous measures unsuccessful:
       - - Surgical cricothyroidotomy (with lidocaine if conscious)

Tactical Evacuation Care

1. Airway Management
   - a. Unconscious casualty without airway obstruction:
     - - Chin lift or jaw thrust maneuver
     - - Nasopharyngeal airway
     - - Place casualty in the recovery position
   - b. Casualty with airway obstruction or impending airway obstruction:
     - - Chin lift or jaw thrust maneuver

- Nasopharyngeal airway
- Allow casualty to assume any position that best protects the airway, to include sitting up.
- Place unconscious casualty in the recovery position.
- If above measures unsuccessful:
    - Supraglottic airway or
    - Endotracheal intubation or
    - Surgical cricothyroidotomy (with lidocaine if conscious).

c. Spinal immobilization is not necessary for casualties with penetrating trauma.

Proposed new Wording
Changes are in red text:

Care Under Fire:

N/A

Tactical Field Care

2. Airway Management

a. Unconscious casualty without airway obstruction:
- Chin lift or jaw thrust maneuver
- Nasopharyngeal airway
- Place casualty in the recovery position

b. Casualty with airway obstruction or impending airway obstruction:
- Chin lift or jaw thrust maneuver
- Nasopharyngeal airway
- Allow casualty to assume any position that best protects the airway, to include sitting up.
- Place unconscious casualty in the recovery position.

c. **If the previous measures are unsuccessful, perform a surgical cricothyroidotomy using one of the following:**
- **CricKey technique (Preferred option)**
- **Bougie-aided open surgical technique using a flanged and cuffed airway cannula of less than 10mm outer diameter, 6-7mm internal diameter, and 5-8cm of intra-tracheal length**
- **Standard open surgical technique using a flanged and cuffed airway cannula of less than 10mm outer diameter, 6-7mm internal diameter, and 5-8cm of intra-tracheal length (Least desirable option)**

Use lidocaine if the casualty is conscious.

Tactical Evacuation Care
* The term "Tactical Evacuation" includes both Casualty Evacuation (CASEVAC) and Medical Evacuation (MEDEVAC) as defined in Joint Publication 4-02.

1. Airway Management
   a. Unconscious casualty without airway obstruction:
      - Chin lift or jaw thrust maneuver
      - Nasopharyngeal airway
      - Place casualty in the recovery position
   b. Casualty with airway obstruction or impending airway obstruction:
      - Chin lift or jaw thrust maneuver
      - Nasopharyngeal airway
      - Allow casualty to assume any position that best protects the airway, to include sitting up.
      - Place unconscious casualty in the recovery position.
      - If **the previous** measures **are** unsuccessful, **assess the tactical and clinical situations, the equipment at hand, and the skills and experience of the person providing care, and then select one of the following airway interventions:**
         - Supraglottic airway, or
         - Endotracheal intubation or
         - **Perform a surgical cricothyroidotomy using one of the following:**
      - **CricKey technique (Preferred option)**
      - **Bougie-aided open surgical technique using a flanged and cuffed airway cannula of less than 10mm outer diameter, 6-7mm internal diameter, and 5-8cm of intra-tracheal length**
      - **Standard open surgical technique using a flanged and cuffed airway cannula of less than 10mm outer diameter, 6-7mm internal diameter, and 5-8cm of intra-tracheal length (Least desirable option)**

      Use lidocaine if the casualty is conscious.
   c. Spinal immobilization is not necessary for casualties with penetrating trauma.

Level of evidence: (AHA/ACC – Tricoci 2009)
The levels of evidence used by the American College of Cardiology and the American Heart Association were outlined by Tricoci in 2009:
- Level A: Evidence from multiple randomized trials or meta-analyses.
- Level B: Evidence from a single randomized trial or nonrandomized studies.
- Level C: Expert opinion, case studies, or standards of care.

Using this taxonomy, the levels of evidence for the following aspects of fluid resuscitation are provided below.

Level of Evidence: B (Mabry 2013, Tricoci 2009)

Vote: Pending

Recommendations for Further Research and Development

1. Improved Surgical Airway Training Methods – performance of a surgical airway is probably the most technically difficult lifesaving intervention that combat medics must master. The use of all possible methods, potentially including live tissue training, advanced and antomically precise airway simulators, and techniques that ensure mastery of airway anatomy knowledge should be evaluated in order to improve the ability of medics to perform this intervention.

2. Optimized Airway Devices for Trauma – new and improved techniques and technologies for securing the injured airway should comtinue to be pursued.

3. Monitoring of airway status, prehospital interventions, and outcomes in combat casualties should be accomplished using information contained in the DoD Trauma Registry.

Acknowledgments

Acknowledgments: Dr. Richard Levitan designed the CK and provided the prototypes used in this study. Airway Cam Technologies, Inc. (Wayne PA) has patents pending on the device.

Disclaimers

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense. This recommendation is intended to be a guideline only and is not a substitute for clinical judgment.

Author Disclosures
The authors have no disclosures.

References:

1. Spaite DW, Joseph M. Pre-hospital cricothyroidotomy: an investigation of indications, technique, complications, and patient outcome. Ann Emerg Med. 1990 Mar;19(3):279-85.

2. Jacobson LE, Gomez GA, Sobieray RJ, Rodman GH, Solotkin KC, Misinski ME. Surgical cricothyroidotomy in trauma patients: analysis of its use by paramedics in the field. J Trauma. 1996 Jul;41(1):15-20.

3. Fortune JB, Judkins DG, Scanzaroli D, McLeod KB, Johnson SB. Efficacy of pre-hospital surgical cricothyroidotomy in trauma patients. J Trauma. 1997May;42(5):832-6; discussion 837-8.

4. Marcolini EG, Burton JH, Bradshaw JR, Baumann MR. A standing-order protocol for cricothyroidotomy in pre-hospital emergency patients. Prehosp Emerg Care. 2004Jan-Mar;8(1):23-8.

5. Assmann NM, Wong DT, Morales E. A comparison of a new indicator-guided with a conventional wire-guided percutaneous cricothyroidotomy device in mannequins. Anesth Analg. 2007 Jul;105(1):148-54.

6. Mabry RL. An analysis of battlefield cricothyroidotomy in Iraq and Afghanistan. J Spec Oper Med. 2012 Spring; 12(1):17-23.

7. Scrase I, Woollard M. Needle vs surgical cricothyroidotomy: a short cut to effective ventilation. Anaesthesia. 2006 Oct; 61(10):962-74. Review.

8. Holmes JF, Panacek EA, Sakles JC, Brofeldt BT. Comparison of 2 cricothyroidotomy techniques: standard method versus rapid 4-step technique. Ann Emerg Med. 1998 Oct; 32(4):442-6.

9. Davis DP, Bramwell KJ, Vilke GM, Cardall TY, Yoshida E, Rosen P. Cricothyroidotomy technique: standard versus the Rapid Four-Step Technique. J Emerg Med. 1999 Jan-Feb; 17(1):17-21.

10. Schaumann N, Lorenz V, Schellongowski P, Staudinger T, Locker GJ, Burgmann H, Pikula B, Hofbauer R, Schuster E, Frass M. Evaluation of Seldinger technique emergency cricothyroidotomy versus standard surgical

cricothyroidotomy in 200 cadavers. Anesthesiology. 2005 Jan;102(1):7-11.

11. King DR, Ogilvie MP, Velmahos G, Alam HB, Demoya MA, Wilcox SR, Mejaddam AY, Van Der Wilden GM, Birkhan OA, Fikry K. Emergent cricothyroidotomies for trauma: training considerations. Am J Emerg Med. 2011 Dec 26.

12. Kelly JF, Ritenour AE, McLaughlin DF, Bagg KA, Apodaca AN, Mallak CT, Pearse L, Lawnick MM, Champion HR, Wade CE, Holcomb JB. Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003-2004 versus 2006. J Trauma. 2008 Feb;64(2 Suppl):S21-6; discussion S26-7

13. Eastridge BJ, Mabry RL, Seguin P, Cantrell J, Tops T, Uribe P, Mallett O, Zubko T, Oetjen-Gerdes L, Rasmussen TE, Butler FK, Kotwal RS, Holcomb JB, Wade C, Champion H, Lawnick M, Moores L, Blackbourne LH. Death on the battlefield (2001-2011): implications for the future of combat casualty care. J Trauma Acute Care Surg. 2012 Dec;73(6 Suppl 5):S431-7.

14. Mariappa V, Stachowski E, Balik M, Clark P, Nayyar V. Cricothyroidotomy: comparison of three different techniques on a porcine airway. Anaesth Intensive Care. 2009 Nov; 37(6):961-7.

15. Sulaiman L, Tighe SQ, Nelson RA. Surgical vs wire-guided cricothyroidotomy: a randomised crossover study of cuffed and uncuffed tracheal tube insertion. Anaesthesia. 2006 Jun; 61(6):565-70.

16. Eisenburger P, Laczika K, List M, Wilfing A, Losert H, Hofbauer R, Burgmann H, Bankl H, Pikula B, Benumof JL, Frass M. Comparison of conventional surgical versus Seldinger technique emergency cricothyroidotomy performed by inexperienced clinicians. Anesthesiology. 2000 Mar; 92(3):687-90.

17. Dimitriadis JC, Paoloni R. Emergency cricothyroidotomy: a randomised crossover study of four methods. Anaesthesia. 2008 Nov; 63(11):1204-8.

18. Cho J, Kang GH, Kim EC, Oh YM, Choi HJ, Im TH, Yang JH, Cho YS, Chung HS. Comparison of manikin versus porcine models in cricothyroidotomy procedure training. Emerg Med J. 2008

19. Johnson DR, Dunlap A, McFeeley P, Gaffney J, Busick B. Cricothyroidotomy performed by pre-hospital personnel: a comparison of two techniques in a human cadaver model. Am J Emerg Med. 1993 May; 11(3):207-9.

20. Benkhadra M, Lenfant F, Nemetz W, Anderhuber F, Feigl G, Fasel J. A comparison of two emergency cricothyroidotomy kits in human cadavers. Anesth Analg. 2008 Jan; 106(1):182-5.

21. Paix BR, Griggs WM. Emergency surgical cricothyroidotomy: 24 successful cases leading to a simple 'scalpel-finger-tube' method. Emerg Med Australas. 2012Feb;24(1):23-30. Nov;25(11):732-4.

22. Narrod JA, Moore EE, Rosen P. Emergency cricothyrostomy--technique and anatomical considerations. J Emerg Med. 1985;2(6):443-6.

23. Walls RM. Cricothyroidotomy. Emerg Med Clin North Am. 1988 Nov;6(4):725-36.

24. Dover K, Howdieshell TR, Colborn GL. The dimensions and vascular anatomy of the cricothyroid membrane: relevance to emergent surgical airway access. Clin Anat. 1996;9(5):291-5.

25. Skill station III: Cricothyroidotomy. In: *Advanced Trauma Life Support for Doctors. ALTS Student Course Manual*. 8th ed. Chicago, IL: American College of Surgeons; 2008:p52.

26. Emergency Surgical Airway Management. In: Nessen SC, Lounsbury DE, Hetz SP, eds. *War Surgery in Afghanistan and Iraq. A series of cases, 2003-2007.* Washington D.C: Borden Institute; 2006:p25.

27. Cricothyroidotomy and Transtracheal Jet Ventilation. In: Roberts JR, Hedges JR, eds. *Clinical Procedures in Emergency Medicine*. 5th ed. Philadelphia, PA: Saunders Elesevier; 2010:110-119.

28. Mabry RL, Edens JW, Pearse L, Kelly JF, Harke H. Fatal airway injuries during Operation Enduring Freedom and Operation Iraqi Freedom. Prehosp Emerg Care. 2010 Apr-Jun;14(2):272-7.

29. P. Goumas, K. Kokkinis, J. Petrocheilos, S. Naxakis, G. Mochloulis; Cricothyroidotomy and the anatomy of the cricothyroid space. An autopsy study. The Journal of Laryngology and Otology.1997 Apr;(111):354-356.

30. MacIntyre A, Markarian MK, Carrison D, Coates J, Kuhls D, Fildes JJ. Three-step emergency cricothyroidotomy. Mil Med. 2007 Dec; 172(12):1228-30.

31. Braude D, Webb H, Stafford J, Stulce P, Montanez L, Kennedy G, Grimsley D. The bougie-aided cricothyroidotomy. Air Med J. 2009 Jul-Aug; 28(4):191-4.

32. Hill C, Reardon R, Joing S, Falvey D, Miner J. Cricothyroidotomy technique using gum elastic bougie is faster than standard technique: a study of emergency medicine residents and medical students in an animal lab. Acad Emerg Med. 2010 Jun;17(6):666-9.

33. Abbrecht PH, Kyle RR, Reams WH, Brunette J. Insertion forces and risk of complications during cricothyroid cannulation. J Emerg Med. 1992 Jul-Aug; 10(4):417-26.

34. Chan TC, Vilke GM, Bramwell KJ, Davis DP, Hamilton RS, Rosen P. Comparison of wire-guided cricothyroidotomy versus standard surgical cricothyroidotomy technique. J Emerg Med. 1999 Nov-Dec; 17(6):957-62.

35. Fikkers BG, van Vugt S, van der Hoeven JG, van den Hoogen FJ, Marres HA. Emergency cricothyroidotomy: a randomised crossover trial comparing the wire-guided and catheter-over-needle techniques. Anaesthesia. 2004 Oct;59(10):1008-11.

36. Latif R, Chhabra N, Ziegler C, Turan A, Carter MB. Teaching the surgical airway using fresh cadavers and confirming placement nonsurgically. J Clin Anesth. 2010 Dec; 22(8):598-602.

37. Paladino L, DuCanto J, Manoach S. Development of a rapid, safe, fiber-optic guided, single-incision cricothyroidotomy using a large ovine model: a pilot study. Resuscitation. 2009 Sep; 80(9):1066-9.

38. Mabry RL, Nichols MC, Shiner DC, Bolleter S, Frankfurt A. A comparison of two open surgical cricothyroidotomy techniques by military medics using a cadaver model. Ann Emerg Med. 2014 Jan;63(1):1-5.

39. Bennett B, Cailteux-Zevallos B, Kotora J: Cricothyroidotomy bottom-up training review: battlefield lessons learned. Mil Med 2011:1311-1320

40. Tricoci P, Allen JM, Kramer JM, Califf RM, Smith SC: Scientific evidence underlying the ACC/AHA Clinical Practice Guidelines. JAMA 2009;301: 831-841

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